Effects of Processing Conditions on Qualities of Rice Fries

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ABSTRACT: Two rice flour mixtures, 2 extruding temperatures, and 2 insert sizes were used to develop rice fries. The extruded material was cut into pieces 7 to 8-cm long, prefried in rice oil at 180°C for 20 s, and kept frozen until final frying for another 70 s. The rice fries were evaluated 5 min and 10 min after final frying for their lipid, moisture, and instrumental texture characteristics. Extruding temperature, rice cultivar, and insert size were significantly related to fat content, moisture, hardness, and fracturability values. A mixture consisting of 80:20 (waxy:long-grain), and extruded at 70 °C using a 6 mm insert, 5 min after frying, gave a texture profile analysis value for hardness, cohesiveness, and gumminess values comparable to commercial potato French fries. The rice fries made by the process also had less than 50% fat than potato fries.

Key Words: rice, long-grain, waxy rice, amylose, rice fries, texture

Introduction

POTATO-BASED FRENCH FRIES ARE A POPULAR FAST FOOD ALL over the world, but are considered to have a high fat content (Anonymous 1977a). Potatoes and rice have very similar proximate compositions on a moisture-free basis (Schwimmer and Burr 1967; Juliano 1992). The rice industry, therefore, has envisioned developing French fry-like food using rice products (Huxsoll and others 1973; Zuckerman 1973). Rice also has many unique properties, such as ease of digestibility, bland flavor, and hypoallergenicity. It is available in many cultivars and is used all over the world to formulate numerous food items. During the last five decades or so, rice has caught the imagination of the United States food processing industry and is being used to make breakfast cereals, snacks, pet foods, and other novel foods.

Two different processes to make French fry-like food from rice have been reported (Huxsoll and others 1973; Zuckerman 1973). These processes involved shaping cooked, whole kernels of rice into french fry-like products using forming devices. However, these processes attracted limited attention probably because the finished product did not have a desirable texture. In an attempt to improve the texture, a recent approach has been to formulate rice fries from milled rice flour using extrusion as a forming device (Kadan and others 1997). One advantage of this approach is the use of broken and immature kernels, which cost less than regular rice. Such products can be easily fortified with protein, fiber, vitamins, and minerals. It is also possible that extrusion cooking may improve the texture characteristics of the rice fry and lower the fat content.

Previous work showed that the degree of hardness was positively correlated to the amylose and protein contents of the rice cultivars (Kadan and others 1997). However, very low amylose or waxy rice imparted sticky texture, which made the rice fry difficult to handle during processing. The water content of the rice fries after prefrying was found to be negatively correlated with hardness and gumminess of the final product (Kadan and others 1997). Subsequent exploratory research indicated that mixtures of long-grain and waxy rice cultivars imparted better texture than single cultivar rice flour. This study, therefore, was designed to evaluate the effects of high and very low-amylose rice flour mixtures, extruding temperatures, and insert sizes (thickness) would have on the moisture, fat absorption, and texture of a rice fry product.

Materials and Methods

Rice cultivars

Two commonly available rice cultivars were obtained commercially. A long-grain, high-amylose rice (Cypress) was a gift from Riceland Foods, Inc., Stuttgart, Ark., U.S.A., and a short-grain glutinous (waxy) rice (NFD 108) was purchased from Farmer's Rice Cooperative, Sacramento, Calif., U.S.A. The rice samples were ground (100 mesh powders), using a pin mill and stored at 4 °C. Moisture, ash, and fiber were determined according to AOAC (1995). Protein contents (N × 5.95) were determined by the combustion method using a nitrogen determinator (Model FP-428, LECO, St. Joseph, Mich., U.S.A.). Lipids were extracted with 100 mL petroleum ether from 5 g of ground rice flour using a Soxhlet extraction apparatus for 6 h (AACC 30 to 20 1995). Amylose content was determined using the simplified assay developed by Juliano (1971).

Extrusion of rice-based fries

Exploratory research had shown that most desirable rice fries, as evaluated by informal taste panels, was made by using the extrusion temperature between 60 and 70 °C, insert size between 5 and 6 mm, and rice flour mixes having between 60 to 80% waxy rice. So the statistical design of 2 × 2 × 2 was conducted to optimize the proper processing condition. Mixtures of rice flour, defatted bran (Riceland Foods, Inc., Stuttgart, Ark., U.S.A.), salt, and glucose (92.3%, 2.7%, 2.3%, and 2.7% respectively) were mixed in a Hobart mixer (Hobart Mfg. Co., Troy, Ohio, U.S.A.) for 10 min. The amounts of defatted bran, salt, and glucose were kept constant for all rice fry samples, while the ratio of waxy and long-grain flour was varied. A Werner Pfleiderer Model ZSK-30 (Ramsey, N.J., U.S.A.), self-cleaning co-rotating twin screw extruder, with square 5 and 6 mm insert (Tanz, Inc. Zion, Ill., U.S.A.) was used. The screws were 975 mm long with the fol-

Table 1. Proximate composition of unextruded rice flours (%)

Rice cultivars	Amylose	Moisture	Protein	Lipid	Ash	Fiber
NFD 108 (waxy)	0.0	12.0	6.4	0.5	0.4	0.2
Cypress (long-grain)	21.5	12.1	8.2	0.7	0.5	0.1
Defatted rice bran[1]	—	11.7	16.5	2.8	9.9	5.1

[1]Riceland Foods,Inc. Stuttgart, Ark.

Table 2. Moisture and lipid of experimental rice fries[1]

Waxy: long-grain (%)	Temp (°C)	Insert (mm)	Moisture (%)		Lipid (%)	
			Prefry	Fry	Prefry	Fry
60:40	60	5	26.0de	11.1d	15.2a	19.8a
60:40	60	6	29.5a	18.1a	10.8d	13.8d
60:40	70	5	25.5e	10.8d	12.3bc	15.8c
60:40	70	6	28.1bc	15.7b	8.8e	16.3c
80:20	60	5	26.9cd	12.0cd	14.2a	20.5a
80:20	60	6	29.9a	20.2a	11.8cd	18.0b
80:20	70	5	25.1e	13.5c	12.9b	16.7c
80:20	70	6	28.7ab	19.1a	9.6e	11.6e
French fry[2]	—	—	—	37.0 ± 0.1	—	23.2 ± 0.4

[1]Means not followed by common letters in the same column differ significantly based on LSD comparison at $P < 0.05$, n = 9.
[2]Commercial French fry purchased from a fast food establishment.

lowing configuration from feed to die: (number of elements-screw flight pitch / length in mm) 1-spacer / 10, 2 - 42 / 42, 1 - 42 / 21, 2 - 42 / 42, 5 - 28 / 28, 5 - kneading block with 45° offset / 20, 4 - 28 / 28, 5 - kneading block with 90° offset / 28, 20 - 20 / 20, and 2 - spacer / 1. All zones (1 through 5) were set at 60 °C or 70 °C. The extrudate temperature was taken via a thermocouple located behind the die plate, which contained the insert and was less than 5 °C below Zone 5. The screw speed was set at 100 rpm with a feed rate of 100 g/min. Moisture of the flour mixture was increased by adding 50 mL deionized water/100 g mix via a water port located in Zone 1. The strands were supported by hand into a flat tray until they were approximately 30 cm long. They were then cut, placed on a table, and allowed to cool at room temperature (about 23 °C) for about 15 to 20 min. They were subsequently cut into 7 to 8 cm-long pieces. Each strand was prefried in rice oil (Riceland Foods, Inc., Stuttgart, Ark., U.S.A.) at 180 °C for 20 s, cooled to room temperature (about 23 °C), put into a Ziploc® plastic bag, and held at 18 °C until refried. For evaluation, the prefried frozen samples were again fried in rice oil at 180 °C for 70 s. The moisture of the extruded pieces, prefried and refried fries, was determined as described above. The dried materials from the moisture analysis were used to determine their fat contents by AACC methods described earlier.

Texture profile analysis (TPA)

The frozen prefries were refried in rice oil at 180 °C for 70 s. Each sample was analyzed three times. One rice fry, cooled to room temperature, from each batch was analyzed at 5 and 10 min intervals for its texture characteristics. The analyzer (Model TA-XT2, Texture Technologies Corp., Scarsdale, N.Y., U.S.A.) contained a 3.3 mm-wide rectangular flat probe. The rice fry was placed horizontally on the analyzer stage. The texture analyzer settings were as follows: pretest speed, 2 mm/s; test speed, l mm/s; distance, as 30% strain; time, l s; trigger force, 20 g; contact area 33 mm², and threshold, 25 g. The above procedure was repeated for each determination. Real-time data acquisition was accomplished by following a User Guide (Anonymous 1997b). The software calculated hardness, fracturability, springiness, cohesiveness, gumminess, chewiness, and resilience of the rice fry samples (Bourne 1982). The average for each profile was determined by using three runs.

The commercial potato french fry sample was purchased from a major fast food outlet, put in a paper bag to protect its moisture loss, and analyzed for moisture and lipid. It took approximately 10 min to transport the commercial potato fry to our laboratory. Because the commercial fries were prepared where purchased, the evaluation (TPA) of these fries was done at 15 min and 20 min.

Statistical analysis

A completely randomized design with eight treatments, three replications per treatment, and 3 sub samples per replication was followed (Steel and Torrie 1997) to make experimental rice fries. Analysis of Variance (ANOVA) for a completely randomized design with a $2 \times 2 \times 2$ factorial treatment structure was performed on moisture (prefry and final fry), fat content (prefry and final fry), and TPA texture measurements. Means were compared using LSD tests at $P < 0.05$ level of significance. Pearson's correlation coefficient and test of significance were calculated on the 8 treatment means for moisture, fat content, and TPA measurements. PROC GLM and PROC CORR of version 6.12 of the SAS Software was used for this analysis (SAS Institute, Inc. 1997). Treatment means were compared using the Least Significant Difference test with significance declared at 5% or less error ($P \leq 0.05$) (Steel and Torrie 1997).

Results and Discussion

THE PROXIMATE COMPOSITION AND AMYLOSE CONTENTS OF the two rice flours and defatted bran used in formulating the experimental rice fries are shown in Table 1. The amylose content of rice cultivars is considered to be one of the most important characteristics for predicting rice cooking qualities and their use in other foods (Webb 1985). Kadan and others (1997) showed that both amylose and protein content of the rice cultivars affect the texture of rice fries. Table 2 shows the moisture and lipid content after prefrying and final frying of rice fries. Preliminary work indicated that about 40% was the maximum moisture that could be incorporated during extrusion without affecting the handling characteristics of the extruded strands. Therefore, all samples were formulated to have 40% initial moisture that yielded an extrudate with 36% moisture. The moisture of the prefry and final fry progressively decreased during frying, while the lipid content increased.

Although all samples contained about 36% moisture immediately after extrusion, the moisture varied from 25.1 to 29.9% and 10.8 to 20.2% for the prefry and final fry, respectively. The extruded rice fries absorbed 8.8 to 15.2% fat during prefrying, resulting in a final lipid content of 11.6 to 20.5% after final frying. The commercial french fry contained 23.2% lipid. Other fast food fries have been reported to have similar values (Anonymous 1997a). The experimental rice fries therefore had 12 to 50% less calories from fat than the commercial fast food potato fries. The amount of moisture loss and the increase in lipids while using the 5 mm inserts were

Table 3. Texture profile analysis after 5 minutes after frying[1]

Waxy: long-grain (%)	Temp (°C)	Insert (mm)	Hardness (kg)	Fracturability (kg)	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
60:40	60	5	2.03d	1.48bc	0.75ab	0.38a	0.75abc	0.77ab	0.19a
60:40	60	6	0.68c	0.67d	0.80a	0.56a	0.38bc	0.32cd	0.21a
60:40	70	5	2.73a	2.52a	0.82a	0.47a	1.27a	1.06a	0.41a
60:40	70	6	0.74e	0.62d	0.97a	0.54a	0.40bc	0.38bcd	0.52a
80:20	60	5	2.19c	1.46c	0.68b	0.39a	0.90ab	0.60bc	0.21a
80:20	60	6	0.40f	0.29d	0.80ab	0.55a	0.22c	0.18cd	0.19a
80:20	70	5	2.48b	1.97b	0.77ab	0.41a	1.04a	0.80ab	0.16a
80:20	70	6	0.34f	0.29d	0.76ab	0.54a	0.23c	0.14d	0.19a
French fry[2]			0.38	0.40	0.95	0.59	0.23	0.22	0.29

[1]Means not followed by common letters in the same column differ significantly based on LSD comparison at P < 0.05, n = 9.
[2]Commercial French fry purchased from a fast food establishment.

Table 4. Texture profile analysis after 10 minutes after frying[1]

Waxy: long-grain (%)	Temp (°C)	Insert (mm)	Hardness (kg)	Fracturability (kg)	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
60:40	60	5	3.00b	2.81a	0.78bc	0.41b	1.18bc	0.95b	0.18b
60:40	60	6	1.30c	0.83bc	0.85ab	0.55a	0.71d	0.58cd	0.23b
60:40	70	5	3.68a	2.84a	0.83abc	0.36b	1.34ab	1.19a	0.57a
60:40	70	6	1.53c	1.32b	0.81bc	0.53a	0.79d	0.64c	0.21b
80:20	60	5	2.92b	2.47a	0.69c	0.34b	1.00c	0.69c	0.29b
80:20	60	6	0.71d	0.47c	0.89ab	0.58a	0.41e	0.34e	0.21b
80:20	70	5	3.81a	2.96a	0.76bc	0.40b	1.37a	1.08ab	0.15b
80:20	70	6	0.70d	0.62bc	0.97a	0.57a	0.40e	0.39de	0.27b
French fry[2]			0.63	0.59	1.73	0.54	0.32	0.53	0.23

[1]Means not followed by common letters in the same column differ significantly based on LSD comparison at P < 0.05, n = 9.[2]Commercial French fry purchased from a fast food establishment.

significantly different when compared with their 6 mm counterpart. Based on mean comparison shown in Table 2, the moisture and lipids of the experimental rice fries showed that the sample extruded using 6 mm inserts lost less moisture and absorbed significantly less fat during frying than those for which 5 mm inserts were used. The effects of rice flour composition and extrusion temperature on final moisture and fat absorption of experimental rice fries were not very pronounced. The ANOVA showed that the insert size and extrusion temperatures highly affected the prefry moisture (P < 0.01).

Based on the results from the analysis of variance and mean comparison, the insert size and percent long grain considerably affected the final fry moisture. There was a significant effect for all three processing parameters and their interactions on the final lipid content of the final fry, except the main effect of percent long grain. Efforts to see the effects at higher than 70 °C or lower than 60 °C extruding temperatures did not prove successful. At 80 °C, the extrudate from both 40% and 20% long-grain mixes was very sticky and hence difficult to process, whereas at 50 °C the extrudates were crumbly. Similarly, both insert sizes and rice flour mixtures either below or above the ranges investigated affected the texture deleteriously.

Table 3 shows the effects of extrusion temperature, insert size, and rice flour composition on TPA values after 5 min of final frying. It should be pointed out that these TPA values are different from the descriptive intensity scales used in sensory analysis (Meilgaard and others 1991). The TPA values are mathematically calculated from the texture curves, using a Stable Micro Systems program (Anonymous 1997b). Based on mean comparison shown in Table 3, TPA 5 min hardness values indicate that samples in which a 5 mm insert was used always imparted higher values than those in which a 6 mm insert was used. All 3 processing variables and their two-way interaction had significant effects (P < 0.05). The fracturability values also were higher with the smaller insert than with larger inserts. The values for springiness, cohesiveness, gumminess, chewiness, and resilience did not appear to show a clear pattern and the ANOVA also, with the exception of the insert size, did not have any effect on the processing variables or their interactions. The hardness and fracturability values indicated that experimental rice fries made from 80:20 rice flour mixture, using 6 mm inserts and extruded at either 60 or 70 °C were comparable to commercial fast food potato french fries. The TPA values of the rice fries after 10 min of cooling to 23 °C are given in Table 4. All the values for 10 min increased when compared with 5 min TPA values. The values for the fast food french fries also followed the same trend.

Pearson's correlation coefficients' analysis data (not shown) indicated that a decrease in the final fry moisture caused an increase in hardness (r = ⁻0.93), fracturability (r = ⁻0.88), gumminess (r = 0.89), and chewiness (r = ⁻0.92) at P < 0.001. There was also an increase in moisture correlated with chewiness (r = 0.83) at P < 0.01.

Conclusions

THE RICE FRIES PRODUCED USING 6 MM INSERTS IMPARTED softer texture, higher moisture, and had lower fat content than 5 mm inserts. The lowest fat-containing rice fries were produced with rice flour mixture containing 20% high amylose (long-grain) and 80% waxy rice flours. This composition, processed in combination with 70 °C extrusion temperature and 6 mm insert produced rice fries having TPA values

for hardness, cohesiveness, and gumminess comparable to commercial fast food potato French fries. The rice fries thus produced had nearly half the fat content of commercial potato fries. However, these rice fries still had some objectionable sticky characteristics during mastication. Other techniques, such as coating the extrudate with gum solutions before frying and imparting holes in the extrudate during processing, should be explored to further improve the texture.

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